CLAIMS

We claim:

1. Apparatus for computational adaptive imaging including:

an image information acquirer providing information relating to the refractive characteristics in a three-dimensional imaged volume;

a ray tracer, utilizing the information relating to the refractive characteristics to trace a multiplicity of rays from a multiplicity of locations in the three-dimensional imaged volume through the three-dimensional imaged volume, thereby providing a location dependent point spread function; and

a deconvolver, utilizing the location dependent point spread function, to provide an output image corrected for distortions due to variations in the refractive characteristics in the three-dimensional imaged volume.

2. Apparatus according to claim 1 wherein the acquirer is adapted to obtain refractive index information from DIC, for example from phase microscopy or from fluorescence.

3. Apparatus according to claim 1 wherein the acquirer is adapted to utilize previously determined refractive characteristics.

4. Apparatus for computational adaptive imaging according to claim 1 and wherein the image information acquirer acquires at least two three-dimensional images of a three-dimensional imaged volume, at least one of the two three-dimensional images containing the information relating to the refractive characteristics in a three-dimensional imaged volume.

5. Apparatus according to claim 4 and wherein the image acquirer acquires at least three three-dimensional images of the three-dimensional imaged volume.

6. Apparatus according to claim 4 and wherein the image acquirer acquires a

plurality of three-dimensional images of the three-dimensional imaged volume, each the image having a discrete wavelength band.

7. Apparatus according to claim 4 and wherein the image acquirer acquires a multiplicity of three-dimensional images of the three-dimensional imaged volume, each the image having a wavelength band which is part of a continuum represented by the wavelength bands of the multiplicity of three-dimensional images.

8. Apparatus according to claim 4 wherein the image acquirer acquires a single three-dimensional image of the three-dimensional image volume.

9. Apparatus according to claim 4 and wherein the ray tracer and the deconvolver utilize the information relating to the refractive characteristics in a three-dimensional imaged volume obtained from one of the three-dimensional images to correct at least another one of the three-dimensional images.

10. Apparatus according to claim 9 wherein the ray tracer includes effects on the image of absorptions, reflections and scattering in the sample.

11. Apparatus according to claim 1, and wherein the three-dimensional images are electromagnetic energy images.

12. Apparatus according to claim 11 and wherein the three-dimensional images are infrared images.

13. Apparatus according to claim 1, and wherein the three-dimensional images are non-electromagnetic images.

14. Apparatus according to claim 1, and wherein the image acquirer receives digital image data from a digital image source and derives therefrom the information

relating to the refractive characteristics in a three-dimensional imaged volume.

15. Apparatus according to claim 1, and wherein the image acquirer, the ray tracer and the deconvolver operate repeatedly over time to provide a multiplicity of output images, each corrected for distortions due to variations in the refractive characteristics in the three-dimensional imaged volume.

16. Apparatus according to claim 1, and wherein the output image is an acoustic image and the refractive characteristics are characteristics of a material which the passage of acoustic energy therethrough.

17. Apparatus according to claim 1, and wherein the output image is an electromagnetic image and the refractive characteristics are characteristics of a material which the passage of electromagnetic energy therethrough.

18. A method for computational adaptive imaging including the steps of:

providing information relating to the refractive characteristics in a three-dimensional imaged volume;

ray tracing, utilizing the information relating to the refractive characteristics, a multiplicity of rays from a multiplicity of locations in the three-dimensional imaged volume through the three-dimensional imaged volume, thereby providing a location dependent point spread function; and

deconvoluting, utilizing the location dependent point spread function, thereby providing an output image corrected for distortions due to variations in the refractive characteristics in the three-dimensional imaged volume.

19. A method according to claim 18, for adding in the imaging path a three-dimensional medium (anti-sample) with refractive properties that correct for the distortions of the three-dimensional sample.

20. A method for computational adaptive imaging according to claim 18 and wherein the step of providing information includes acquiring at least two three-dimensional images of a three-dimensional imaged volume, at least one of the two three-dimensional images containing the information relating to the refractive characteristics in a three-dimensional imaged volume.

21. A method according to claim 20 and wherein the step of providing information includes acquiring at least three three-dimensional images of a three-dimensional imaged volume.

22. A method according to claim 20 and wherein the step of providing information includes acquiring a plurality of three-dimensional images of the three-dimensional imaged volume, each the image having a discrete wavelength band.

23. A method according to claim 20 and wherein the step of providing information includes acquiring a multiplicity of three-dimensional images of the three-dimensional imaged volume, each the image having a wavelength band which is part of a continuum represented by the wavelength bands of the multiplicity of three-dimensional images.

24. A method according to claim 18, and wherein the three-dimensional images are electromagnetic energy images.

25. A method according to claim 24 and wherein the three-dimensional images are infrared images.

26. A method according to claim 18, and wherein the three-dimensional images are non-electromagnetic images.

27. A method according to claim 18, and wherein the step of providing

includes receiving digital image data from a digital image source and deriving therefrom the information relating to the refractive characteristics along a multiplicity of light paths in a three-dimensional imaged volume.

28. A method according to claim 18, and wherein the steps of providing information, ray tracing and deconvoluting operate repeatedly over time to provide a multiplicity of output images, each corrected for distortions due to variations in the refractive characteristics in the three-dimensional imaged volume.

29. A method according to claim 28 wherein the refractive characteristics are estimated.

30. Apparatus for utilizing differential interference contrast images to provide three-dimensional refractive index information including a line integrator operating on differential interference contrast images displaying a directional derivative of refractive index of an object to invert the directional derivative thereof, thereby providing a plurality of two-dimensional representations of the refractive index of the object.

31. Apparatus for utilizing differential interference contrast images to provide three-dimensional refractive index information according to claim 30 and also including a deconvolver performing deconvolution of the plurality of two-dimensional representations of the refractive index of the object, thereby reducing out-of-focus contributions to the two-dimensional representations of the refractive index of the object.

32. A method for utilizing differential interference contrast images to provide three-dimensional refractive index information including performing line integration on differential interference contrast images displaying a directional derivative of refractive index of an object to invert the directional derivative thereof, thereby providing a plurality of two-dimensional representations of the refractive index of the object.

33. A method for utilizing differential interference contrast images to provide three-dimensional refractive index information according to claim 32 and also including performing deconvolution of the plurality of two-dimensional representations of the refractive index of the object, thereby reducing out-of-focus contributions to the two-dimensional representations of the refractive index of the object.

Sub B1

34. Apparatus for ray tracing through a medium having multiple variations in refractive index including:

a computer employing an analytically determined path of a ray through the multiplicity of locations in the medium, for a plurality of rays impinging thereon in different directions, by utilizing known local variation of the refractive index at a multiplicity of locations in the medium.

35. A method of ray tracing through a medium having multiple variations in refractive index including:

determining local variation of the refractive index at a multiplicity of locations in the medium;

analytically determining the path of a ray through the multiplicity of locations in the medium, for a plurality of rays impinging thereon in different directions.

36. Apparatus for confocal microscopy including:

a ray tracer, employing known variations of the refractive index in a three-dimensional sample for determining the paths of a multiplicity of rays emerging from at least one point in the sample and passing through the sample, thereby determining an aberrated wavefront for each the point; and

an adaptive optics controller utilizing the aberrated wavefront to control an adaptive optical element in a confocal microscope, thereby to correct aberrations resulting from the variations in the refractive index.

37. A method for confocal microscopy including:

determining variations of the refractive index in a three-dimensional sample;

determining the paths of a multiplicity of rays emerging from at least one point in the sample and passing through the sample, thereby determining an aberrated wavefront for each the point; and

utilizing the aberrated wavefront to control an adaptive optical element in a confocal microscope, thereby to correct aberrations resulting from the variations in the refractive index.